Analysis of Learning Curves for Transpedicular Puncture

Análise da curva de aprendizado para punção transpedicular

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Abstract

Objective The authors propose the analysis of quantitative and qualitative learning curves of transpedicular puncture in a manikin-type training simulator model for transpedicular puncture (SMTP)

Methods Six students (S1 to S6) were selected to perform the puncture training under radiological control. Quantitative parameters such as the procedure time (total time spent in performing each procedure) and fluoroscopy time (fluoroscopy usage time for each punch) were analyzed using the Mann-Whitney test. For the qualitative evaluation, the punctures were categorized into type AB (adequate) or CD (inadequate) according to the path and positioning of the needle. Qualitative data were analyzed by Fisher's exact test.

Results The curves of the examination times and fluoroscopy decreased steadily as expected, especially for the trainee S3. In addition, there was a predominance of punctures AB of the third subsequent session; however, this result was statistically significant for the S1 and S2 trainees.

Conclusion The learning curves indicate that qualitative performance improves as students become more familiar with the process.

Keywords

- ► manikin-type training simulator model for transpedicular puncture
- ► transpedicular
- ► puncture
- ► learning curves

Resumo

Objetivo Os autores propõem a análise de curvas de aprendizado quantitativa e qualitativa para punção transpedicular em modelo simulador tipo manequim (SMTP).

Método Foram selecionados seis estudantes (S1 a S6) para treinamento de punção transpedicular sob controle radiológico. Parâmetros quantitativos como tempo de procedimento (tempo total gasto na performance de cada punção) e tempo de fluoroscopia (tempo de utilização fluoroscopia em cada punção) foram analisados através do teste Mann-Whitney. Análise qualitativa categorizada em punção AB (adequada) ou CD (inadequada) de acordo com o trajeto e posicionamento da agulha. Os dados qualitativos foram analisados através do teste de Fisher.

Resultado As curvas dos tempos de exame e fluoroscopia diminuíram de forma constante conforme esperado, especialmente para o estagiário S3. Adicionalmente, houve predominância de punções AB na terceira sessão; entretanto, este resultado foi estatisticamente significante para os estagiários S1 e S2.

Conclusão As curvas de aprendizado qualitativas indicaram melhora da performance a medida que o processo torna-se mais familiar aos estudantes.

Palavras-chave

- ► modelo simulador tipo manequim para punção transpedicular
- ► transpedicular
- ► punção
- ► curva de aprendizado

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Introduction

The increasing use of interventional radiology procedures[1–3] highlights the growing need for medical qualification. In the United States, members of the American Society of Interventional and Therapeutic Neuroradiology, the American Association of Neurological Surgeons, the Neurological Surgeons Congress Section of Cerebrovascular Neurosurgery, and the American Society of Neuroradiology approved by the American College of Graduate Medical Education[1] proposed a training program for residents and trainees in interventional neuroradiology that was created to improve medical training.

The assimilation of a particular procedure can be represented graphically by learning curves[4] showing improved performance during the repetition of a task or particular exercise. Training using experimental models instead of patients increases skills and confidence levels for complex and risky procedures.[5] This study aims to analyze the learning curves generated over a lumbar puncture training program using a simulator model for transpedicular puncture (SMTP),[6] a model that has features similar to the in vivo models. Quantitative parameters were adopted, such as the procedure time for each guided puncturing, and the fluoroscopy time, which corresponds to the period of exposure to X-rays in each puncture. Qualitative parameters were adopted according to the route of the needle and its final positioning.

Materials and Methods

The authors promoted a theoretical course on needling procedures in the spinal column for medical trainees in interventional neuroradiology. At the end of the class, vacancies were offered for practical training on an in vivo model to the students who were interested.

The following criteria for inclusion were adopted: medical specialist in radiology; neurology or neurosurgery registered training program in interventional neuroradiology at least for one year; interest in interventional neuro-radiologic procedures nonvascular; and time availability.

Six volunteers accepted the additional training, including three radiologists (S2, S5 and S6), two neurologists (S1 and S4) and one neurosurgeon (S3); student S3 had additional training prior to 1 year in surgery of the spinal column, while the other students did not have any experience with spinal surgery procedures.

The training sessions were individualized and monitored; the information obtained was stored in a database for future analysis.

The exercise consisted of a transpedicular lumbar puncture via SMTP under fluoroscopic control angiography equipment Philips® Integris V5000 (Philips Healthcare, Best, Netherlands). The bone lancing device Gallini® (Gallini Medical, Mantova, Italy) with a caliber of 12 gauge was used. The goal of this exercise was to position the distal end of the needle at the geometric center of the vertebral body through the transpedicular access. Each student participated in three training sessions over two days with ten punctures per session, totaling thirty procedures. All the punctures were performed with radiological assistance, and required the use of oblique, lateral and anterior projections to view the pedicle and vertebral body.

The quantitative endpoints included procedure time (PT) and fluoroscopy time (FT). For the qualitative evaluation, the punctures were categorized into type AB, considered ideal or adequate, and type CD, which was considered inadequate or poor. In this type of evaluation, the punctured vertebrae were observed in anteroposterior (AP) and profile (P) views. Two vertical lines divided the spine into three columns —two lateral and one median — in the AP projection. In the P view, two vertical parallel lines divided the anterior, medial and posterior segments, and two imaginary horizontal lines defined the upper, middle and lower levels (►**Fig. 1**). The correct positioning of the distal end of the needle in the median column, anterior segment and middle level was evaluated (one point for each). The sum categorizes the puncture as follows: A (3 points), B (2 points), C (1 point) and D (0 points).

The qualitative and quantitative results were statistically analyzed (►**Tables 1–3**). Values from the first and third training sessions were subjected to the nonparametric

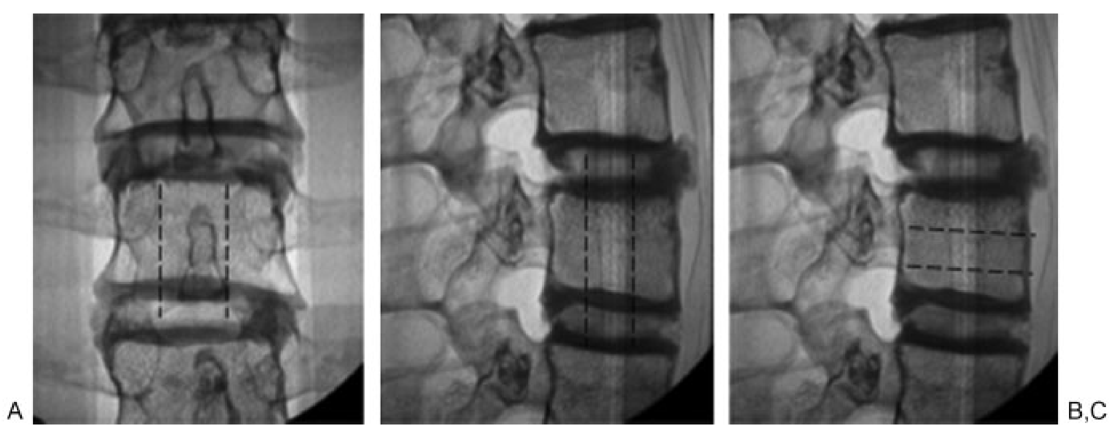

Fig. 1 Radiography of the model spine: (**A**) anteroposterior (AP) view showing the imaginary lines dividing the spine into three columns; (**B** and **C**) profile views showing the imaginary lines dividing the spine into segments (**B**) and levels (**C**).

Table 1 Quality comparisons of training sessions 1 and 3

S1	Session				Total		Fisher's exact test
	1		3				(*p*)
A (ideal) + B (acceptable)	2	20%	9	100%	11	57.9%	
C (inadequate) + D (poor)	8	80%	0	0%	8	42.1%	0.0022*
Total	10	100%	9	100%	19	100%	
S2							
A (ideal) + B (acceptable)	2	20%	10	100%	12	60%	
C (inadequate) + D (poor)	8	80%	0	0%	8	40%	0.0014*
Total	10	100%	10	100%	20	100%	
S3							
A (ideal) + B (acceptable)	5	50%	9	90%	14	70%	
C (inadequate) + D (poor)	5	50%	1	10%	6	30%	0.1432
Total	10	100%	10	100%	20	100%	
S4							
A (ideal) + B (acceptable)	6	60%	10	100%	16	80%	
C (inadequate) + D (poor)	4	40%	0	0%	4	20%	0.0935
Total	10	100%	10	100%	20	100%	
S5							
A (ideal) + B (acceptable)	9	90%	9	100%	18	94.7%	
C (inadequate) + D (poor)	1	10%	0	0%	1	5.3%	1.0000
Total	10	100%	9	100%	19	100%	
S6							
A (ideal) + B (acceptable)	6	75%	8	100%	14	87.5%	
C (inadequate) + D (poor)	2	25%	0	0%	2	12.5%	0.4497
Total	8	100%	8	100%	16	100%	

*The results obtained with the Fisher exact test show an evolution in the puncture pattern between the first and third training sessions. We observed a predominance of AB-type punctures in the last stage of student training, with the exception of the S5 student, who already had AB-type punctures from the first session of puncture exercises.

Fisher's exact test and Mann-Whitney U test to assess the qualitative and quantitative data respectively.

The data were analyzed blindly by an independent neuroradiologist with 10 years of experience in interventional procedures.

Results

Trainees S2, S3 and S5 performed 30 punctures. Due to technical problems that restricted the number of training sessions, S1 and S4 completed 29 punctures, and S6 performed only 25 punctures.

The learning curves for PT and FT show time reductions for all students except S3, whereas the charts show little change or even a slight increase (►**Fig. 2**). The learning curves for qualitative data reflect a predominance of AB punctures from the third session onwards, with student S3 still performing CD punctures at this stage (►**Fig. 2**).

Fisher's exact test for qualitative data shows that S1 and S2 performed better in the last training session, while the Mann-Whitney U test for PT and FT showed an increased response for all students except S3.

Discussion

According to Bloom et al[7], the competence for a particular practice corresponds to interactions between knowledge, skill and attitude. Therefore, a training device is useful for developing practical skills. The presentation of PT learning curves and the application of a nonparametric test for the values obtained in the first and third training sessions show that time was significantly reduced for all students except S3, whose curves remained relatively flat.

Reduced PT can indicate technical improvement, as demonstrated by Newton et al[8] in a study about learning curves for spinal surgery in a goat model, and by Schauer et al[9] in a study of anastomotic gastric bypass surgery. Newton et al[8] analyzed total surgical time and procedure time per disc separately, and found that the time reductions were similar. However, the FT must be evaluated

Table 2 PT comparisons between training sessions 1 and 3

		Session		Mann-Whitney U Test	Result
		1	3	(p)	
S1	Average	3.3	2.2		
	Standard deviation	0.8	0.5	$< 0.001^*$	$1 > 3$
	N	10	9		
S2	Average	8.1	4.6		
	Standard deviation	2.4	1.1	$< 0.001^*$	$1 > 3$
	N	10	10		
S3	Average	4.0	4.1		
	Standard deviation	1.3	0.5	0.218	$1 = 3$
	N	10	10		
S4	Average	4.8	2.0		
	Standard deviation	1.9	0.3	$< 0.001^*$	$1 > 3$
	N	10	10		
S5	Average	4.0	2.2		
	Standard deviation	1.3	0.1	$< 0.001^*$	$1 > 3$
	N	10	9		
S6	Average	2.6	1.4		
	Standard deviation	0.7	0.3	$< 0.001^*$	$1 > 3$
	N	8	8		

Abbreviations: N, number; PT, procedure ime. *Procedure comparison table between the first and third training sessions. A reduction of the procedure time is observed for all students evaluated, except for the S3 student who remained unchanged ($p = 0.218$).

Table 3 FT comparisons between training sessions 1 and 3

		Session		Mann-Whitney U Test	Result
		1	3	(p)	
S1	Average	1.7	1.3		
	Standard deviation	0.4	0.4	0.043^*	$1 > 3$
	N	10	9		
S2	Average	5.5	2.5		
	Standard deviation	1.7	0.8	$< 0.001^*$	$1 > 3$
	N	10	10		
S3	Average	2.2	2.4		
	Standard deviation	0.9	0.5	0.105	$1 = 3$
	N	10	10		
S4	Average	2.9	1.2		
	Standard deviation	1.3	0.2	$< 0.001^*$	$1 > 3$
	N	10	10		
S5	Average	3.3	1.4		
	Standard deviation	1.2	0.2	$< 0.001^*$	$1 > 3$
	N	10	9		
S6	Average	1.3	0.8		
	Standard deviation	0.3	0.2	$< 0.001^*$	$1 > 3$
	N	8	8		

Abbreviations: FT, fluoroscopy time; N, number. *Table comparing fluoroscopy times between the first and third training sessions. A reduction in fluoroscopy time was observed for all the students evaluated, except for the S3 student who remained practically unchanged ($p = 0.105$).

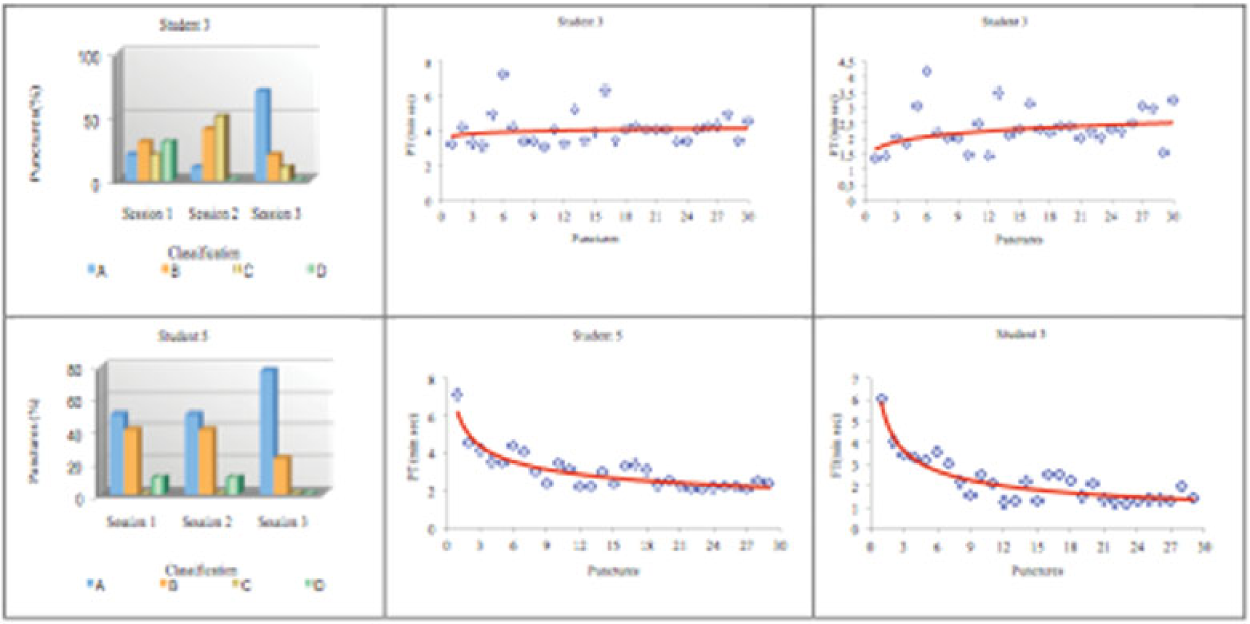

Fig. 2 Comparison of learning curves in terms of puncture type, PT and FT between trainees S3 and S5 (S5 had a better performance).

separately because it only corresponds to a portion of the training, that is, the PT may be broader independent of the FT. The optimization of fluoroscopy, in turn, may reduce the PT. There was a clear reduction in FT for all students. These differences were deemed to be significant by the Mann-Whitney U test for all students except S3, who exhibited almost no variation. Given the low baseline values of S3's first training session, the lack of variation is likely explained by his previous neurosurgical training in a medical residency program, his experience in neurosurgery spinal practice, and his familiarity with the transpedicular route using fluoroscopic assistance. The authors believe that surgical expertise is an advantage, as it offers prior knowledge of the step-by-step process.

The use of qualitative parameters to assess learning curves has been proposed by several authors for different types of procedures, including the endovascular treatment of intracranial aneurysms,[10] gastric anastomosis,[9] and video-assisted thoracoscopy.[11] These studies measured blood loss, length of hospitalization, infection rates, complications and other parameters without the use of simulators or phantom models. Conversely, Uribe et al[12] evaluated learning curves by qualitative parameters, specifically a score, when using an ES3 simulator for endoscopic procedures. We believe that the use of categories rather than a score demonstrates more clearly an acceptable or ideal puncture rather than an inappropriate or dangerous one. Our results show a predominance of ideal or acceptable punctures in the third session.

Hernandez et al[13] performed a study with a surgical simulator, and used a qualitative evaluation technique called objective structured assessment of technical skill (OSATS). However, there is no similar technique for the spinal transpedicular route. Thus, we used our own radiological references to design the technical parameters of the SMTP model to allow qualitative assessment.

The puncture type results show gradual progress with training. Only S3 performed CD punctures in the third session. However, Fisher's exact test shows significant differences only for S1 and S2. This effect was observed because, although the categorization used is a useful reference for the students, it also reduces variability between the first and the third sessions, which is an essential condition for a classically shaped learning curve.

Our findings suggest that quantitative curve patterns might be more appropriate for this model because a qualitative gain was not obtained in all cases. A qualitative increase, in theory, provides assurance to authorize students to perform the procedures on patients. This statement corroborates the findings of Lieberman et al[14] in a study on stereotactic breast biopsies.

Conclusions

The learning curves for the quantitative parameters and statistical test results show performance improvements that reflect increased understanding of the procedure over time. Regarding the learning curves for the qualitative parameters, only two students showed a favorable pattern. This type of observation does not disqualify the proposed training model; rather, it indicates the importance of a positive attitude toward training.

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No other potential relevant conflicts of interest to this article were reported.

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